Hybrid Method for Measurement of Rotational Structural Dynamic Properties

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Rotational structural dynamic responses are typically not measured in modal survey testing due to the lack of adequate procedures or instrumentation. In the residual flexibility free-suspension method, the inclusion of rotational terms could (1) improve the process of updating finite element models using test data and (2) enhance the applicability of the residual technique for various industries. Due to the difficulty of measuring rotational residual flexibilities, the current study considers the possibility of attaching rectangular masses to the interface regions, or trunnions, of a space shuttle payload simulator (fig. 83) to amplify rotational motion of the trunnions and enhance their measurement.

The purpose of this research is to investigate use of a hybrid free-suspension modal testing method for measurement of rotational frequency response functions and residual flexibility. The work is part of an ongoing effort to perform shuttle payload modal vibration testing more accurately and less expensively than in the past.

The subject hybrid technique combines the mass-additive and residual flexibility techniques that have been studied for potential application to shuttle payloads during the past several years at MSFC. The mass-additive approach involves the measurement and use of free-free modes of the structure with mass-loaded boundaries or interface degrees of freedom, and the residual flexibility method requires the free-free modes and residual flexibility of the interfaces. In both cases, shuttle orbiter-constrained modes are derived using a summation of free-boundary modes.

Although ongoing in-house research has shown that the mass-additive approach is less desirable than the residual flexibility method for verifying shuttle payload models, it has features that are very attractive when considered in terms of a hybrid modal test method. In particular, rotational measurements for the payload interfaces (trunnions) become possible when a rectangular mass is used to increase the angular motions and provide a means of using translational accelerometers. Measurement of rotational structural dynamic properties historically has been very difficult, and it appears that a practical rotational accelerometer has yet to be developed. For this reason, only translational data is generally taken during modal tests. Although payload interface rotations are not constrained by the orbiter, the availability of rotational frequency response function data could be useful in model correlation. Further, rotational measurements are of great interest to the structural dynamics community in general. One drawback to the residual flexibility approach has been the difficulty in obtaining rotational data for general boundary conditions.

The research includes the following tasks: (1) derivation of hybrid equations; (2) use of a simple test article dynamically similar to shuttle payloads (fig. 83), at least in the orbiter interface regions; (3) calculation of free-free mode shapes, frequencies, and interface residual flexibilities for the article with mass-loaded interfaces; (4) measurement of free-free modes, frequencies, and residuals for the simple test article with a mass-loaded trunnion interface; (5) estimation of rotational frequency response and residual functions in the absence of interface mass-loading; and (6) discussion of using rotational frequency response function data for model correlation. Step 5 provides the desired result: the rotational frequency response (acceleration/force ratio) and residual flexibility estimated for the trunnion without mass-loading. This requires some analytical work once the mass-loaded rotations have been measured.

Hybrid equations have been derived for the residual approach to allow the use of mass-loading at desired points on the structure. The effects of the masses have been analytically removed to derive the constrained mode shapes of the structure without mass-loading. In the past year, rotational frequency response measurements were made using a simple payload simulator structure having trunnion interfaces (fig. 83). A small mass was attached to one of the four trunnions (fig. 84), and was instrumented with accelerometers to allow estimation of the trunnion attach-point rotations.

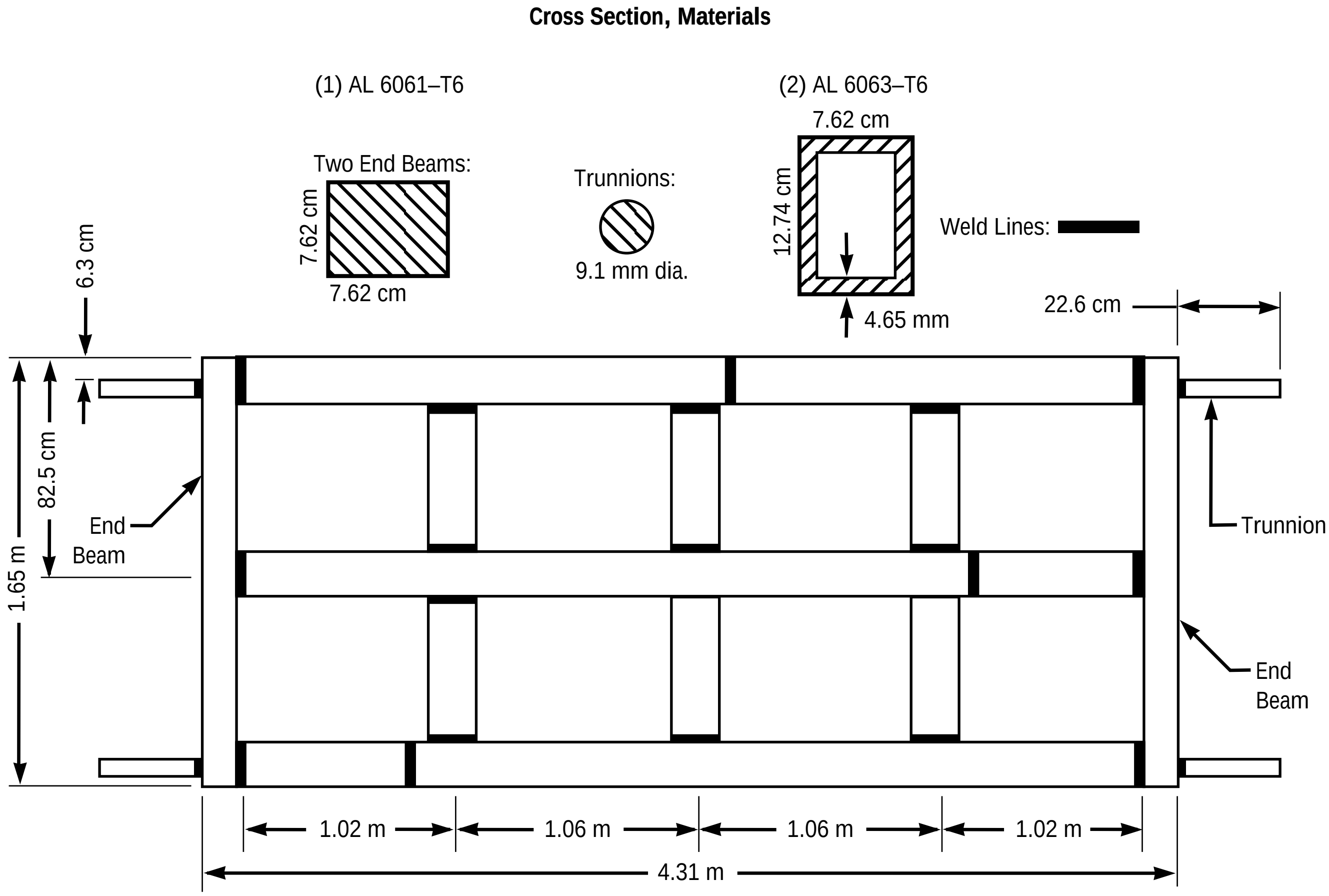

Figure 83.—Space shuttle payload simulator.

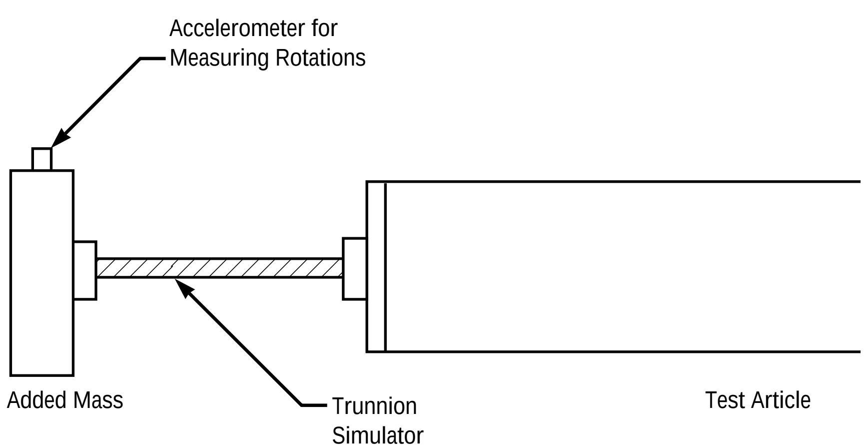

Figure 84.—Illustration of test setup for measuring rotational response.

Work remaining to be done is as follows: (1) calculate rotational trunnion responses for the payload simulator structure with mass-loading and compare with the measurements made this past year, (2) write computer code to estimate the rotational responses without mass-loaded trunnions, and (3) complete checkout of the code that was modified in fiscal year 1994 to include mass addition in the computation of residual flexibility. A fourth task is being considered to measure rotations with a mobile mass unit that can be attached at any desired point on the structure.

Admire, J.R.; Tinker, M.L.; and Ivey, E.W. January 1994. Residual Flexibility Test Method for Verification of Constrained Structural Models. *American Institute of Aeronautics and Astronautics Journal*, 32:1:170–175.

Admire, J.R.; Tinker, M.L.; and Ivey, E.W. November 1993. Mass-Additive Modal Test Method for Verification of Constrained Structural Models. *American Institute of Aeronautics and Astronautics Journal*, 31:11:2, 148–53.

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